K_L^o SECONDARY BEAM CHARACTERISTICS

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The mean decay distance of a 100-GeV K_s^o meson is 5.4 meters. Any experiment involving the direct production of K_s^o mesons at a primary target will necessarily have to be performed well within the meson shield and in the vicinity of the first optical elements of the charged beams. To provide such facilities at the first target station seems unwise. Tertiary beam intensities of K_s^o produced outside the meson shield will be sufficient for many experiments.

The amplitude for ordinary K_s^o decay becomes comparable to the CP-violating two-pion decay of the K_L^o in about 12 K_s^o mean lives--or a distance of 212 feet. Therefore, at a distance of 400 feet or so where the first experiments become possible, the beams may be considered as pure, or nearly pure, K_L^o beams.

K_L^o Intensity

Hagedorn and Ranft[1] give intensities for K^+ and K^- production by 200-GeV protons. The intensity of K_L^o production has been taken to be the average of the K^+ and K^- intensities. Figure 1 shows the K_L^o production intensities as a function of angle for 100 GeV to 20 GeV K_L^o's.

The units are particles produced per GeV of secondary particle momentum, per steradian of solid angle, for each interacting primary proton.

A K_L^o beam can contain a solid angle of the order of 10^{-6} steradians, but is more likely to contain about 4×10^{-8} steradians, which is about a 1-in. square collimator 400 feet from the target. Thus a 4×10^{-8} steradian beam at 5 milliradians production angle from 10^{13} protons interacting in the primary target contains 0.88×10^5 100-GeV K_L^o per GeV of K^o energy, and about ten times as many 20-GeV K_L^o. This is quite an intense beam. Table I contains other typical beam intensity calculations.

Neutron Background

The principal barrier to the use of intense K_L^o beams is frequently the neutron background, and the energy of the background neutrons is not of interest in many experiments. The curves of Hagedorn and Ranft for proton production by protons have been taken to be characteristic for neutron production also. These curves have been roughly integrated graphically over energy to give Fig. 2, the number of neutrons (i.e. protons) produced per steradian for each interacting primary proton given as a function of production angle.

Incidentally the curve of Fig. 2 has been roughly integrated over angle. This integration gives 0.45 neutrons (i.e. protons) produced per indicent proton in the forward 15 milliradians and a rather indeterminate number, not far from 0.5, at somewhat larger angles. This is reasonable--at least to factors of 2 or so.

The neutron background in our example of a 4×10^{-8} steradian beam at 5 milliradians from 10^{13} interacting protons is 5.2×10^{8} neutrons. Such a beam creates an experimental problem for the equipment and a serious health hazard that must be shielded very carefully.

In an experiment run primarily for 100-GeV K_L^o, one might be concerned with K_L^o in a region of 100± 20 GeV. This "useful" K_L^o flux is 3.5×10^{6} per 10^{13} protons and the total neutron background is the 5.2×10^{8} calculated above. One can think very roughly, then, of 100 : 1 ratios of neutrons to useful K_L^o. This is not very different from beams that are now used at the AGS and ZGS.

In the high energy regeneration experiment, the neutrons with energies above 100 GeV are serious background; a discussion of this background problem is given by Smith and Wattenberg, NAL Summer Study Report B. 4-68-27.

Desirable Angles for K_L^o Beams

Absolute intensity seems quite adequate for most K_L^o beam experiments so that the quality of the beam is determined primarily by the K_L^o to neutron ratio.

Figure 3 gives the ratio of K_L^o to total neutron intensity for several K_L^o energies as well as for an integrated K_L^o spectrum. The best angle to use for 100-GeV K_L^o is about 7.5 milliradians and for 20-GeV K_L^o is about 27.5 milliradians. There is no single best angle, but if one had a free choice it would probably be about 12.5 milliradians.

For practical targeting considerations see the note in this report on Targeting for Neutral Beams (B. 4-68-106).

Table I. Fluxes of K_L^o of Various Energies as a Function of Angle From 10^{13} Protons Interacting with a $\Delta p = 1$ GeV/c and $\Delta\Omega = 4 \times 10^{-8}$ Steradians.

Beam Angle mrad	40 GeV	80 GeV	100 GeV
5	5.8×10^5	2.2×10^5	0.9×10^5
7.5	4.3×10^5	1.1×10^5	4.5×10^4
10.0	2.9×10^5	5.3×10^4	1.3×10^4
12.5	2×10^5	2.2×10^4	3×10^3

FIGURE CAPTIONS

Fig. 1. K_L^o intensity vs production angle for several different energies.

Fig. 2. Neutron production vs angle, integrated over all energies.

Fig. 3. Relative intensity of K_L^o to total neutron intensity, as a function of K^o energy and production angle.

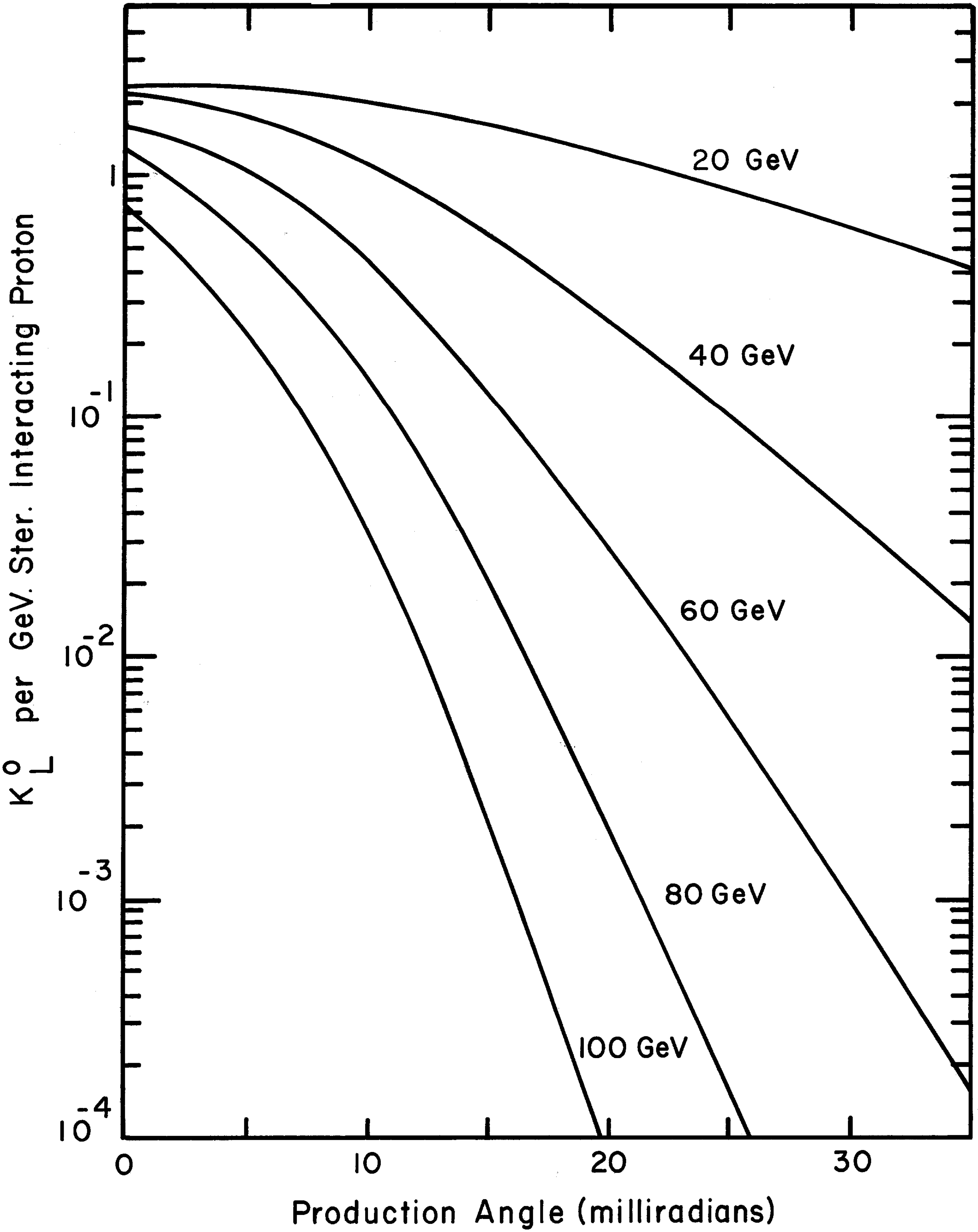
K^o_L per GeV. Ster. Interacting Proton
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
20 GeV
40 GeV
60 GeV
80 GeV
100 GeV
0
10
20
30
Production Angle (milliradians)

Fig. 1

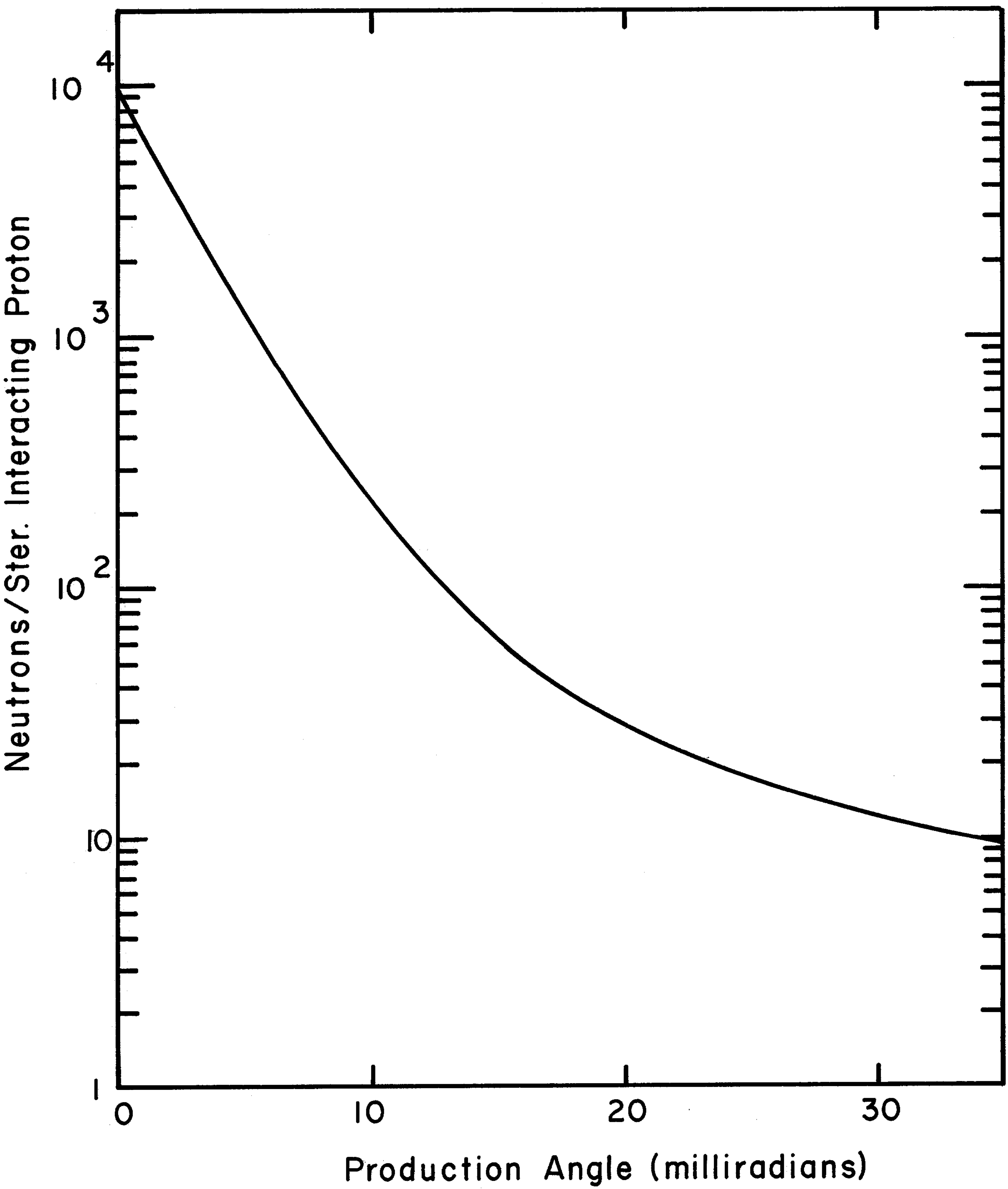
Neutrons/Ster. Interacting Proton
10^4
10^3
10^2
10
1
0
10
20
30
Production Angle (milliradians)

Fig. 2

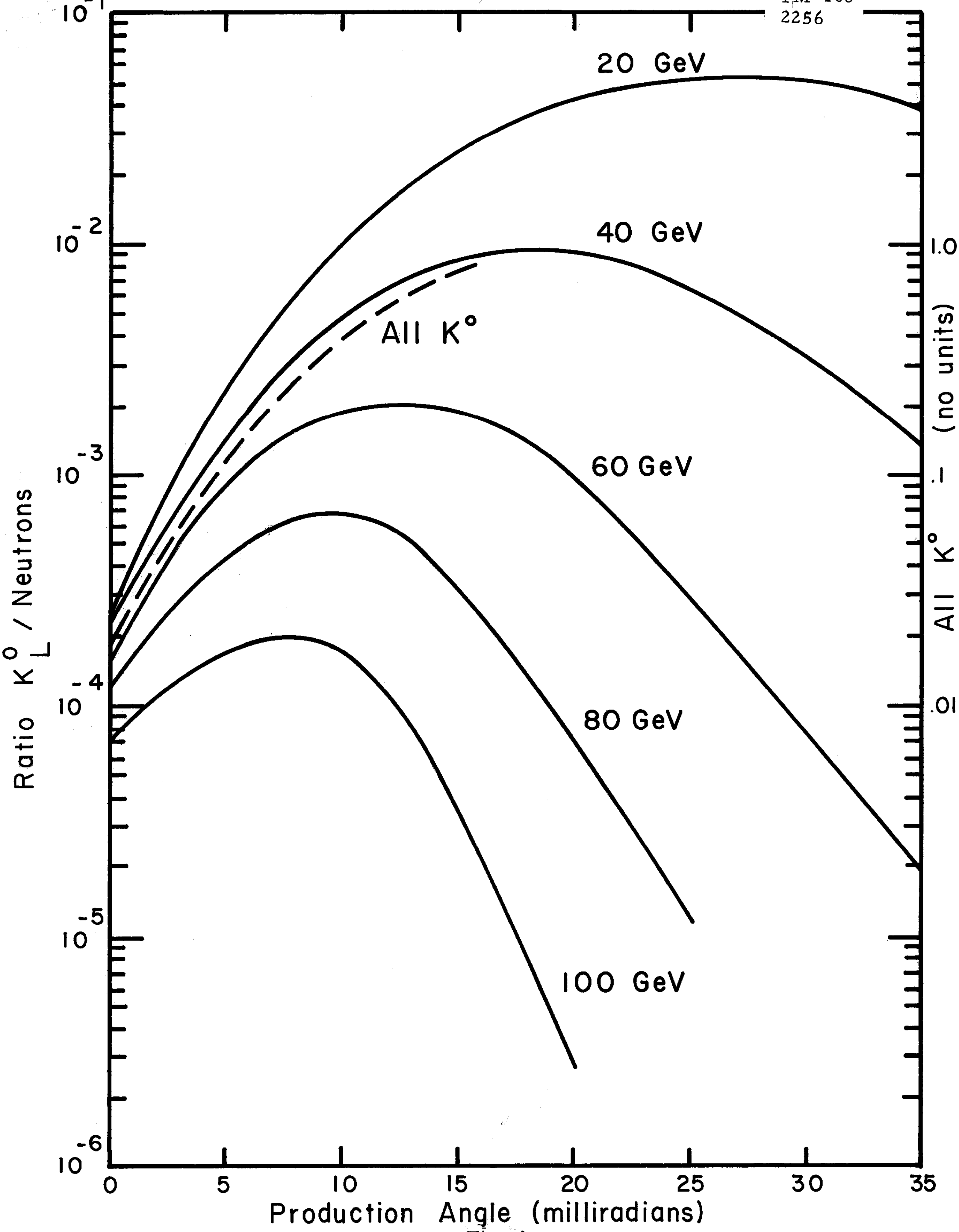
20 GeV
40 GeV
All K°
60 GeV
80 GeV
100 GeV
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
1.0
.1
.01
All K° (no units)
Ratio K^o_L / Neutrons
0
5
10
15
20
25
30
35
Production Angle (milliradians)

Fig. 3